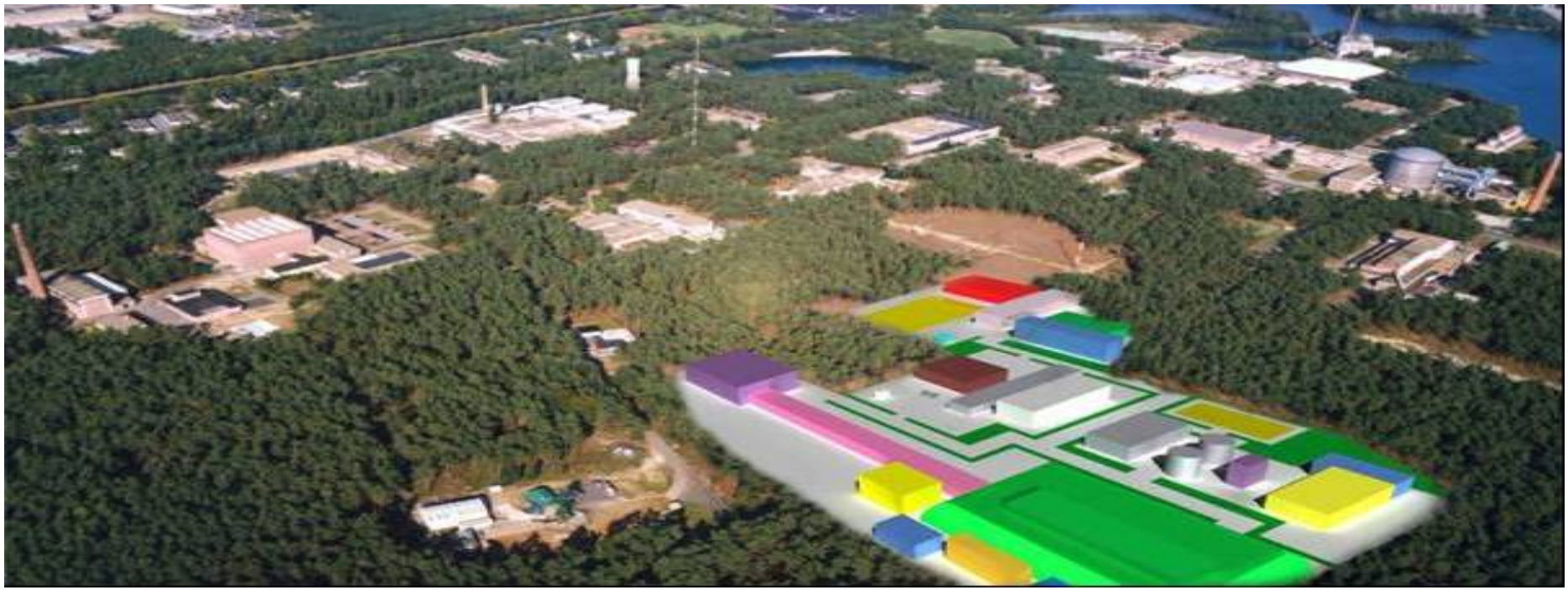
MYRRHA

A Fast Spectrum Pb-Bi Cooled Experimental Facility in Belgium



Hamid Aït Abderrahim

Nuclear physics research at the MYRRHA accelerator

BRIX anual workshop

April 7-9, 2008

SCK•CEN

- Belgian Nuclear Research Centre: a foundation under the Belgian federal Ministry of Energy
- created in 1952, cradle of nuclear research and energy development in Belgium
- portfolio and tradition of first-of-a-kind projects
  - BR2, BR3
  - MOX-development
  - Dismantling of BR3
  - Underground lab
- major spin-offs
  - IRE
  - Belgonucleaire
  - Euridice

SCK•CEN
≡
international experience

- SCK•CEN has 55 years hands on experience
- SCK•CEN continues the historical Belgian openness to international collaboration and undertakings (EURODIF, EUROCHEMIC, PAMELA, RJH…)
- SCK•CEN performs collaboration and contractual work worldwide in most of its disciplines
  - Europe: Belgium, France, UK, Germany, Spain, Switzerland, Russia, ….
  - Asia: Japan, Korea, China, Saudi-Arabia….
  - America's: USA, Argentina, Brazil, Mexico,….
  - Africa: Algeria, South-Africa, …..
- SCK•CEN actively participates in international organisations and their activities
  - IAEA, OECD/NEA, ASTM, USNRC, …
  - European Union programs: Euratom; FP4 thru FP7

Research towards a sustainable option?...

CO_2 free

concentrated

economic

safety

waste

supply

social acceptability

research & development

SCK•CEN Vision: Contribute to a Sustainable Nuclear Energy Opt.

- Today's thermal spectrum reactors
  - Needed in the energy mix
  - No efficient use of resources & HLW burden
  - ➔Provide services & support to Gen.II & III NPPs
  - ➔R&D on Reduction of HLW burden through P&T and Minor Actinide recycling in fast spectrum dedicated burners (critical or sub-critical) ⇨ MYRRHA
- Fast reactors needed to meet sustainability
  - Closed fuel cycle ⇨ reduce proliferation risk
  - Closed fuel cycle ⇨ better use of resources (U, Th)
  - Reduce the HLW flow
  - ➔Move towards fast spectrum reactors and demonstrate one of the proposed GEN.IV concepts ⇨ LFR
- Very long term sustainability through contribution to Fusion systems

Fast Spectrum Experimental Facility needed in Europe

MYRRHA is to be:

- A flexible irradiation testing facility in replacement of the SCK•CEN MTR BR2 (100 MW)
- An attractive fast spectrum testing facility in Europe for Gen.IV and Fusion
- A full step ADS demo facility and P&T testing facility
- A technological prototype as test bench for LFR Gen.IV
- An attractive tool for education and training of young scientists and engineers
- A medical radioisotope production facility
- …What about Nuclear Physics thanks to its accelerator

The MYRRHA-concept

neutron multiplier

p → n spallation

proton-accelerator

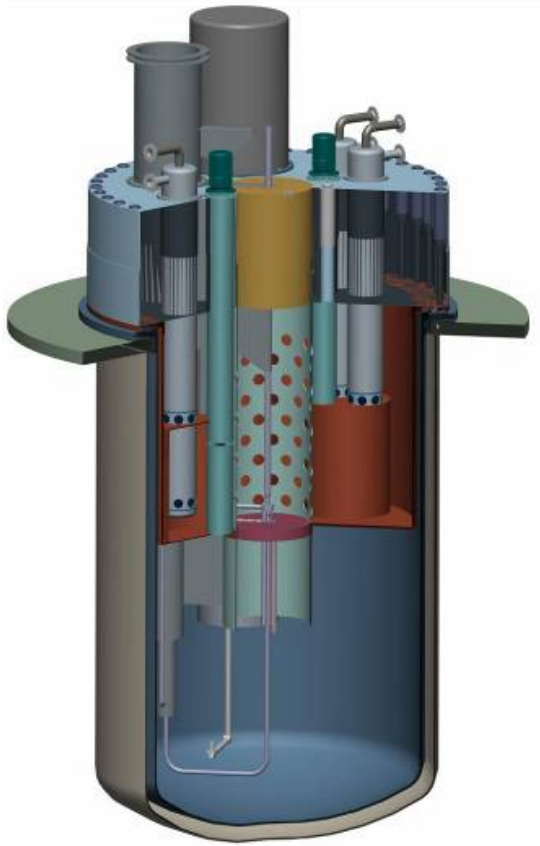
multi-disciplinary

'fast' neutron source

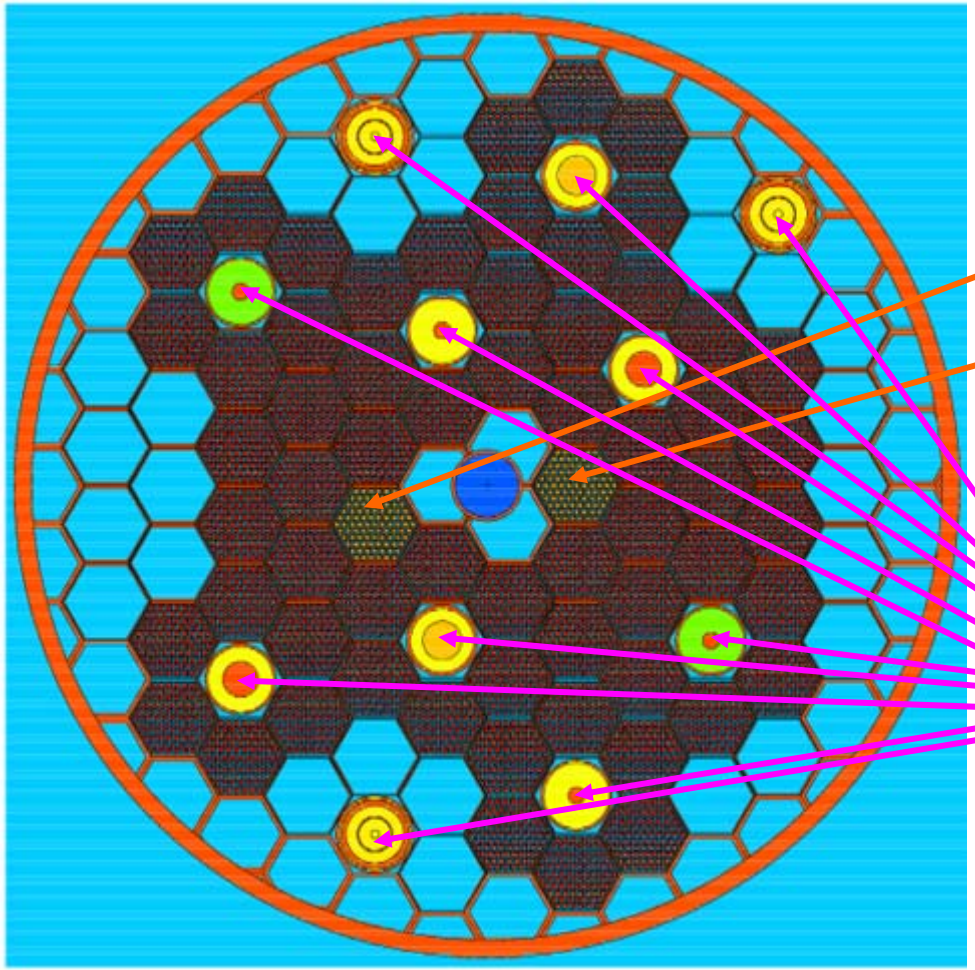
Pb/Bi as spallation source and coolant

LFR Demonstration

transmutation Long lived waste



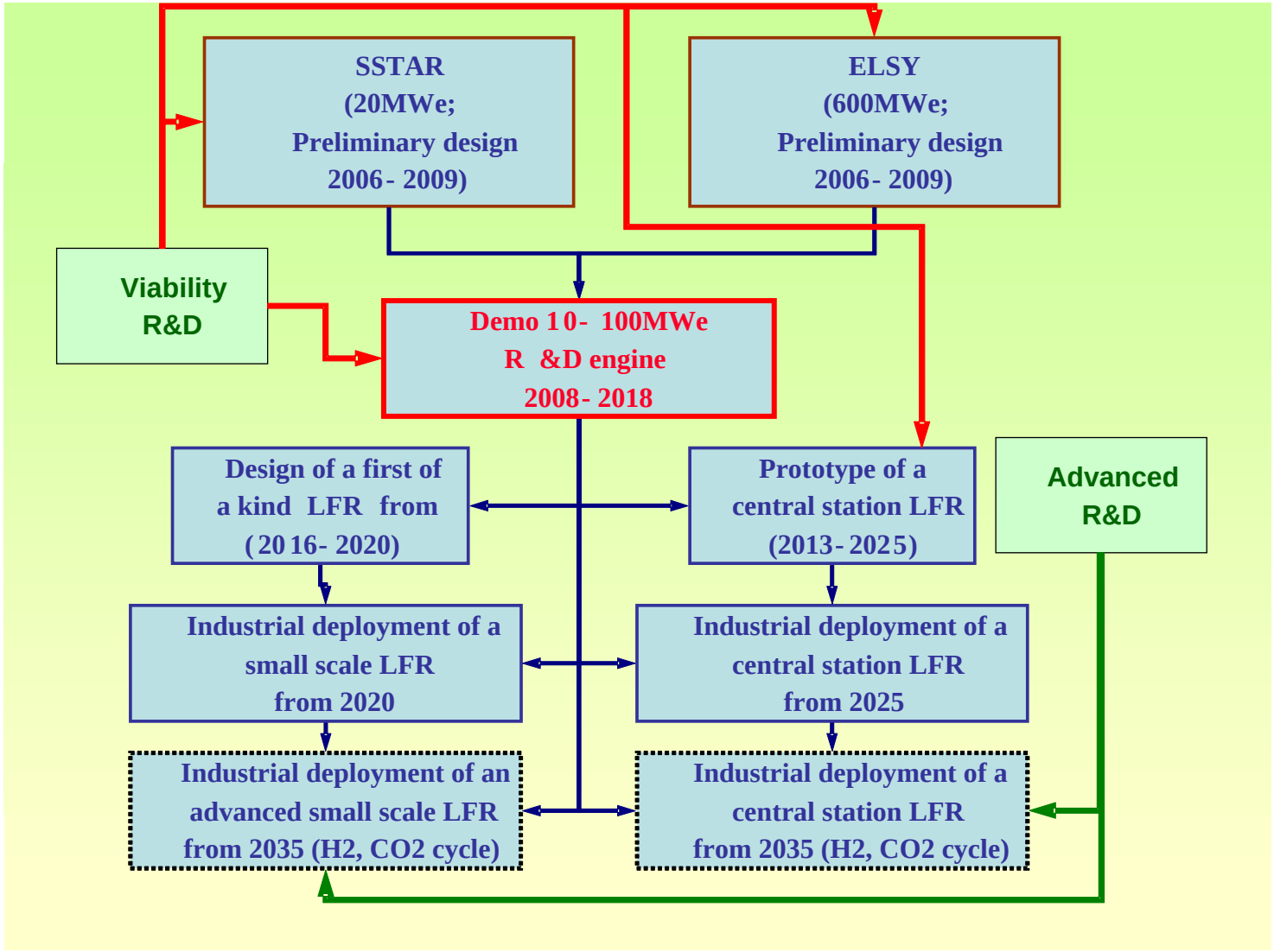
MYRRHA: a Flexible Experimental Facility



Minor Actinides test assemblies

Experimental rigs:
- dedicated contents
- dedicated irradiation

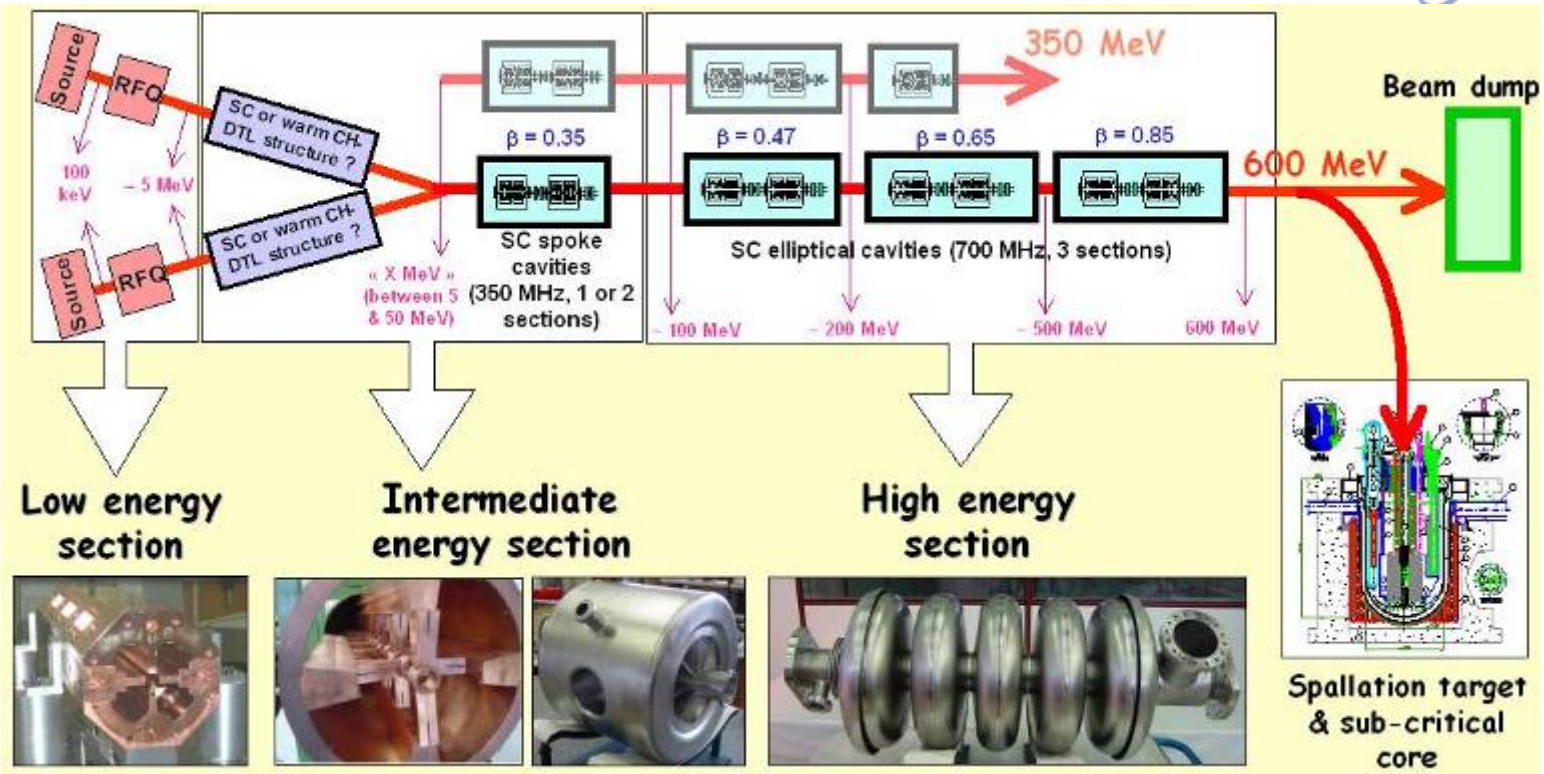
Link ADS – Gen. IV LFR



MYRRHA components

- **ACCELERATOR**
- SPALLATION SOURCE
- SUB-CRITICAL REACTOR

Accelerator LINAC solution



- Strong R&D & construction programs for SC linacs are underway worldwide
  - Spallation Sources for Neutron Science,
  - Radioactive Ions & Neutrino Beam Facilities,
  - Irradiation Facilities

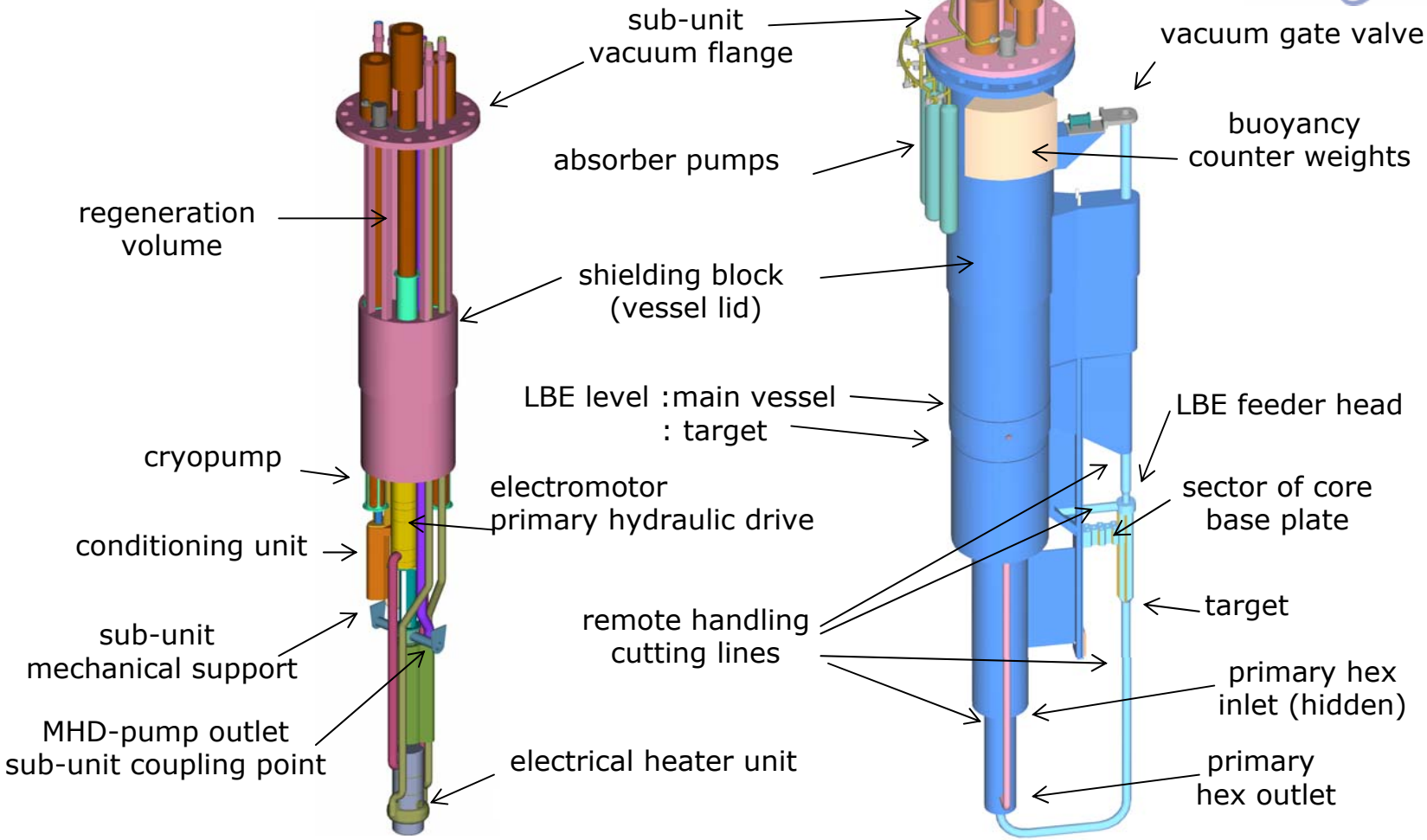
Pb-Bi HLM use for Spallation Target & cooling the Reactor

- ☺ Undergoes spallation
- ☺ Reasonable melting temperature (123 °C)
- ☺ Water can be used for the secondary cooling
- ☹ High coolant density
- ☹ Opaque: blind fuel handling, In-Service Inspection
- ☹ Possibly deposits of high melting point phases
- ☹ Bi activates into Po
- ☹ Pb-Bi corrosion of structural and cladding materials

MYRRHA components

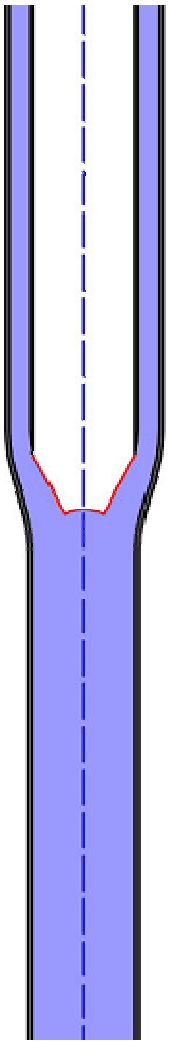
- ACCELERATOR
- **SPALLATION SOURCE**
- SUB-CRITICAL REACTOR

Spallation loop and sub-unit *

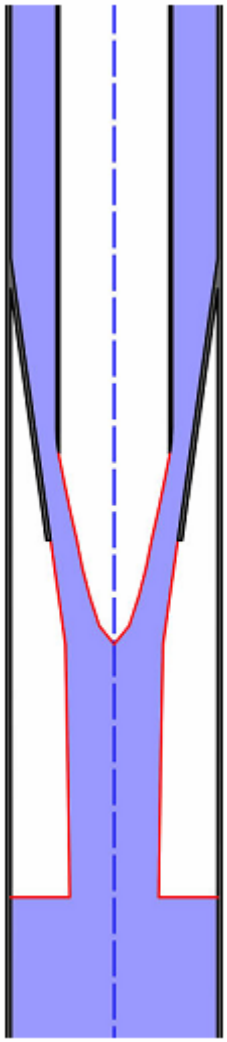


*** Based on the MYRRHA draft 2 design, SCK/CEN, Mol**

Nozzle design

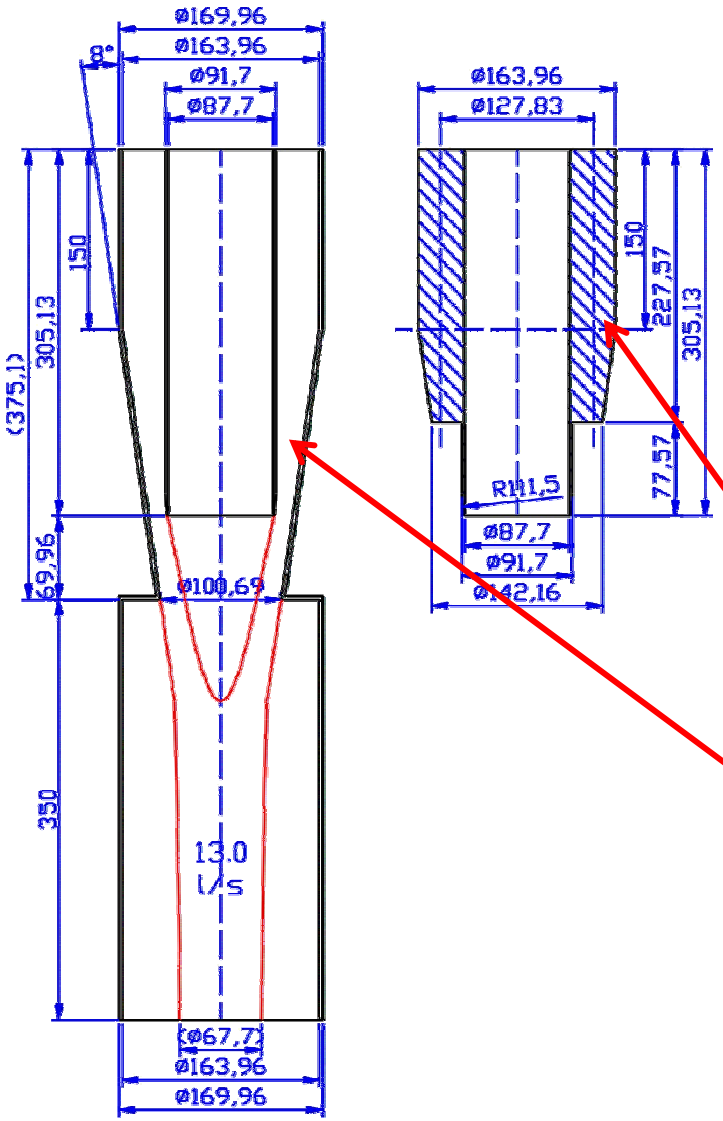


- MYRRHA draft2
- no flow detachment allowed
- shape / height target free surface must be actively controlled by LIDAR / MHD pump



- XT-ADS
- flow detachment enforced
- shape / height target free surface only determined by nozzle geometry and flowrate
- extra free surface act as buffer during beam transients

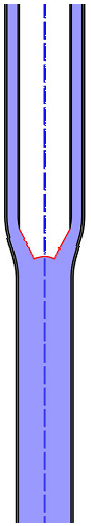
Current reference nozzle as agreed during Petten meeting



- **"version": v0.10**
- **13l/s flowrate**
- **concentric design**
  - **demonstrate that a nozzle with flow detachment works**
  - **feeder cross section equivalent to a "three feeder" target**
  - **basis for "three feeder" target**
- **drag enhancer with 100 vertical channels to achieve enough friction force to compensate the force of gravity and make the flow less turbulent**
- **the last part of the nozzle accelerates the flow, taking over the function of the drag enhancer for compensation of the gravity force**

Free surface level monitoring

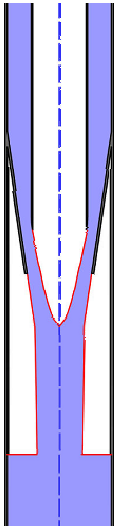
MYRRHA



- active control of height of the target free surface
- specifications in MYRRHA draft2 document
- 1 kHz time resolution
- 1 mm height resolution
- specified LIDAR system not commercially available

XT-ADS

- no active control of height of the target free surface
- level measurement only required for safety reasons to detect a possible filling of the beam tube
- new specifications are proposed
  - 2 Hz time resolution
  - 1 cm height resolution
- comes into reach of commercially available LIDAR systems

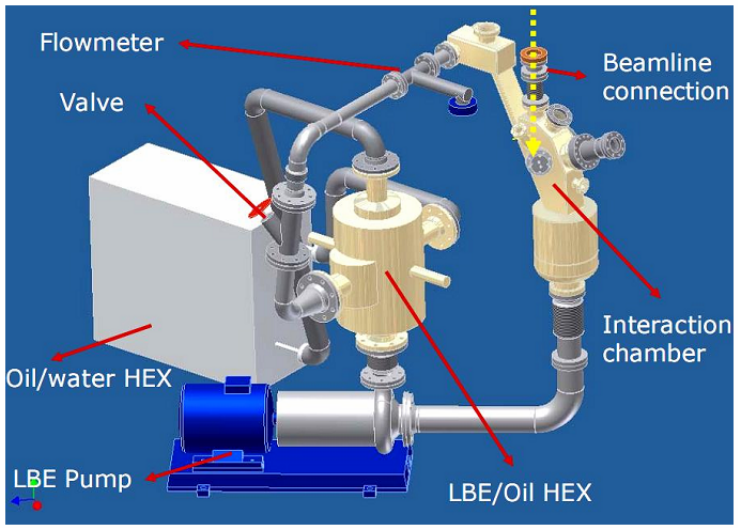


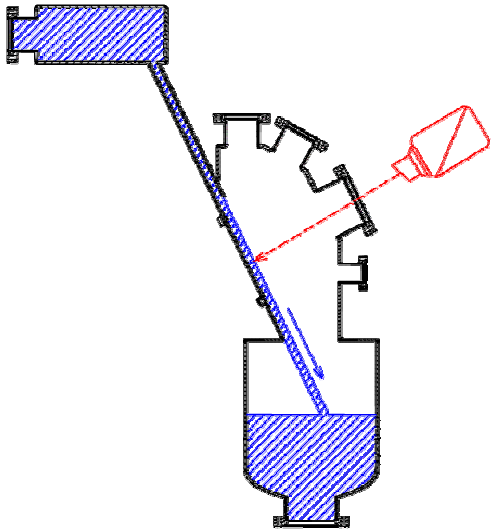
LIDAR to measure distance towards flowing LBE

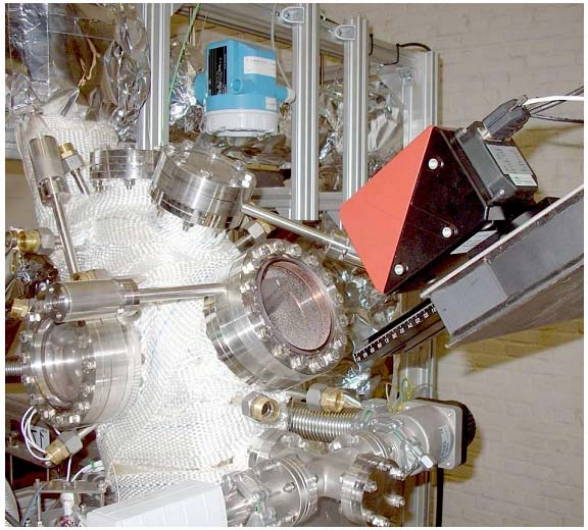
- "Normal" surface for commercial LIDAR systems
  - diffuse reflection
  - quasi constant reflection properties

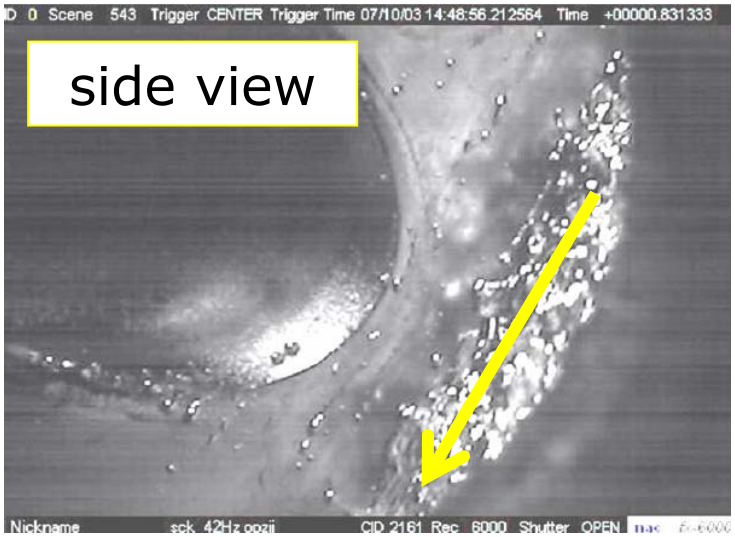
- XT-ADS target surface
  - turbulent LBE liquid metal
  - specular reflection
  - average reflection properties will depend on the size of the laser spot
  - laser spot < turbulent features of the flow: large and fast variations in reflected signal amplitude: LIDAR system will have problems
  - laser spot >> turbulent features of the flow: reflection properties will average out and will seem to be more diffuse reflecting: should be OK for commercial LIDAR system

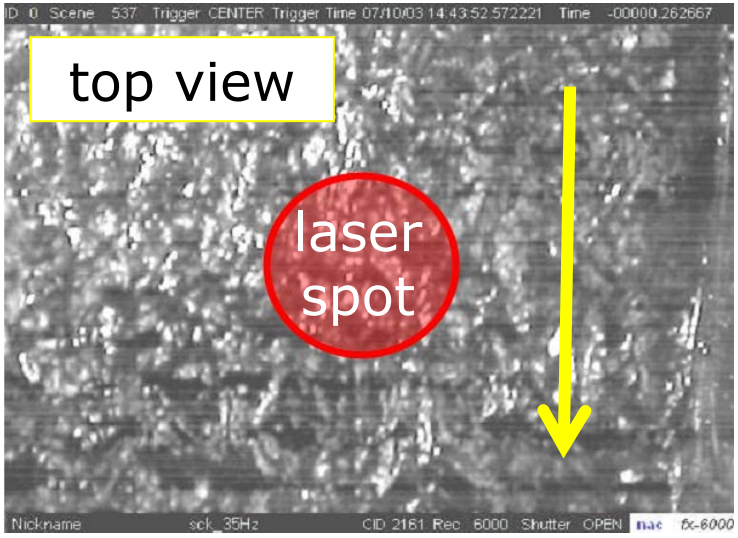
WEBEXPIR LBE loop as LIDAR test bench







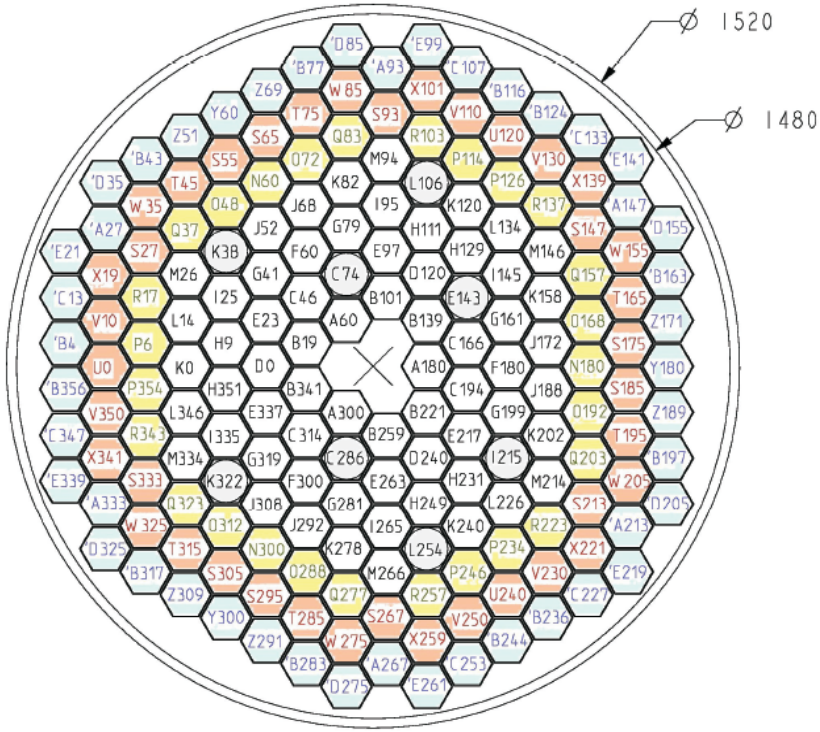




MYRRHA components

- ACCELERATOR
- SPALLATION SOURCE
- **SUB-CRITICAL REACTOR**

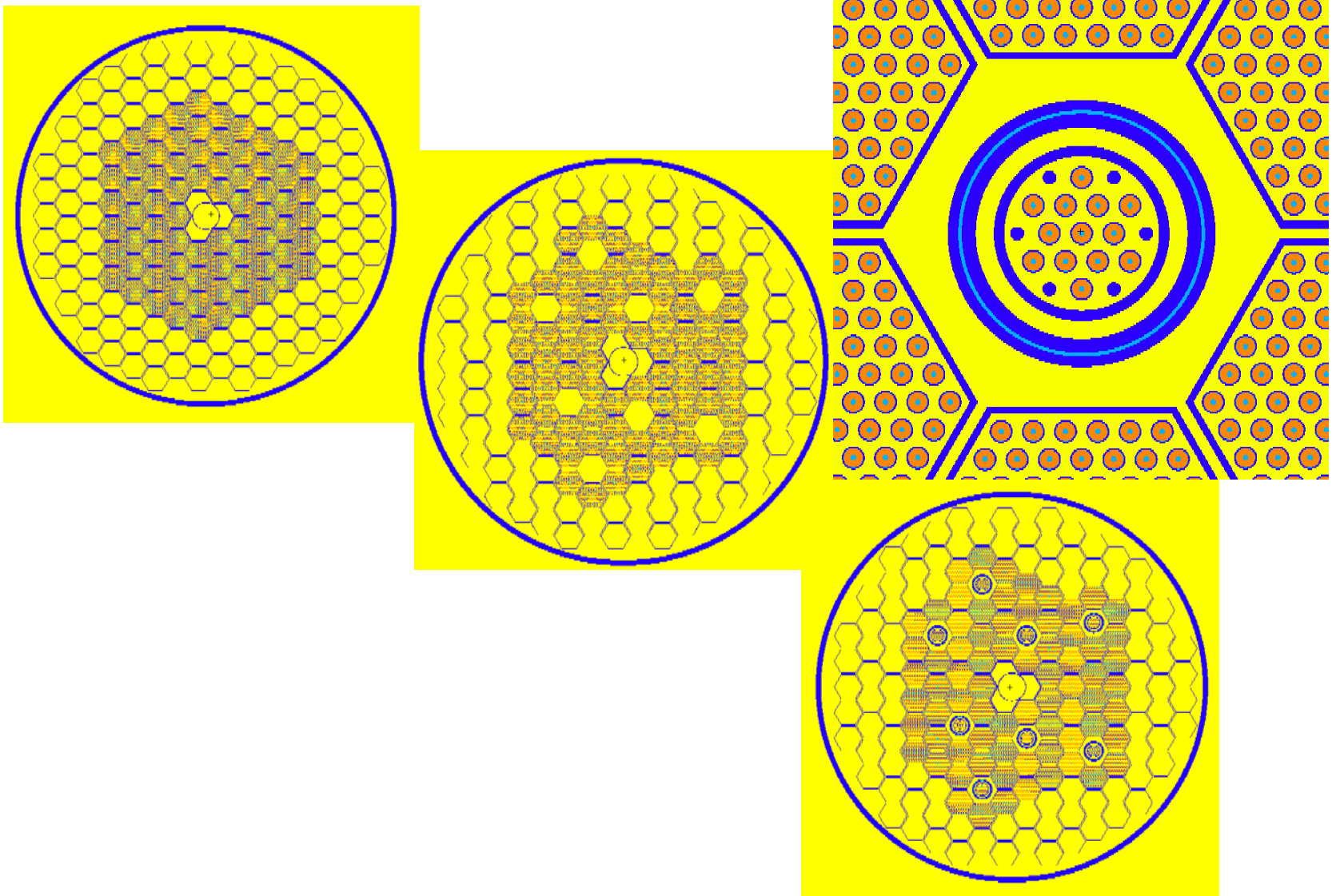
New core layout



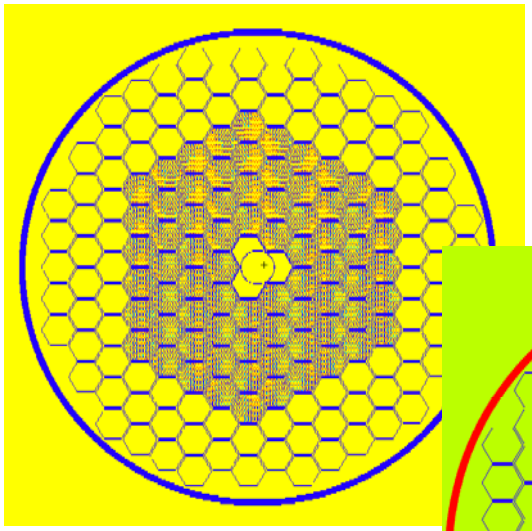
Proposed reference XT-ADS core - Option B

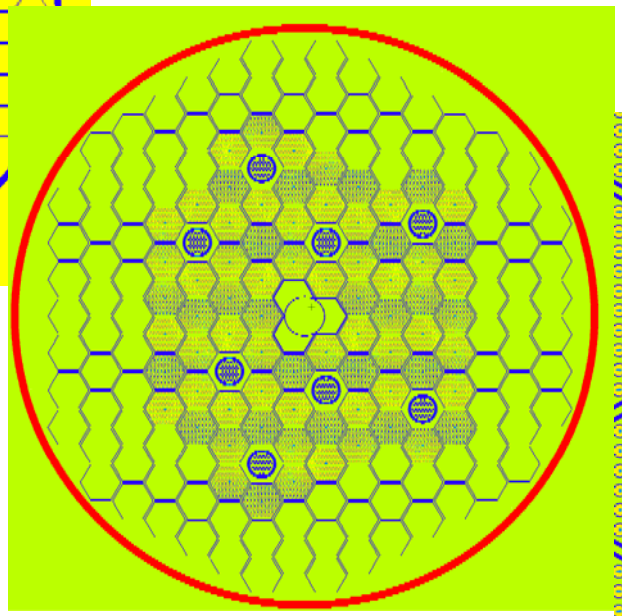
99 original positions
39 positions for assemblies filled with LBE and B_4C at ends (orange)
45 positions for assies filled with B_4C pins (light blue)
183 positions in total

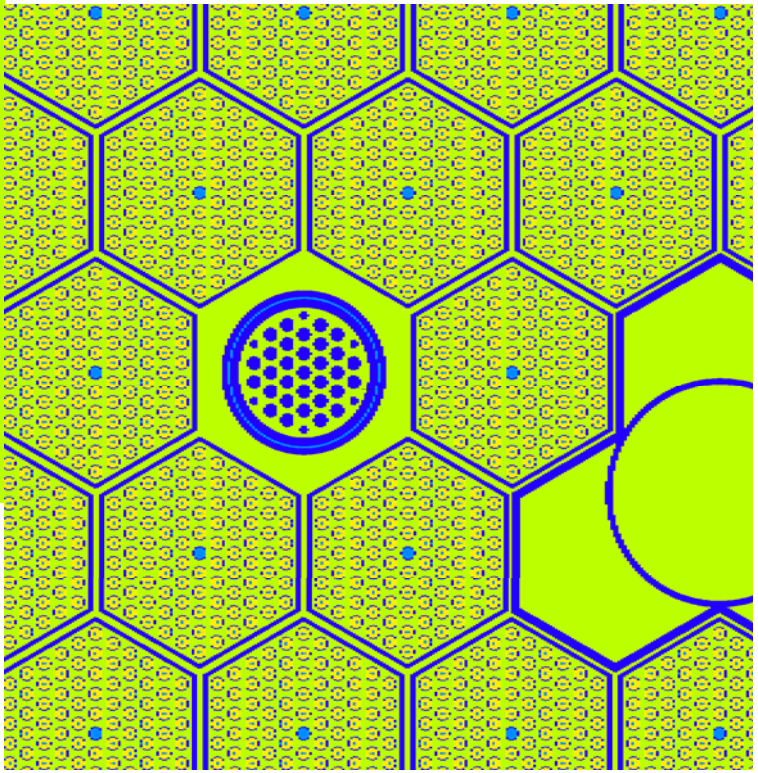
From C0 over P0 to P1



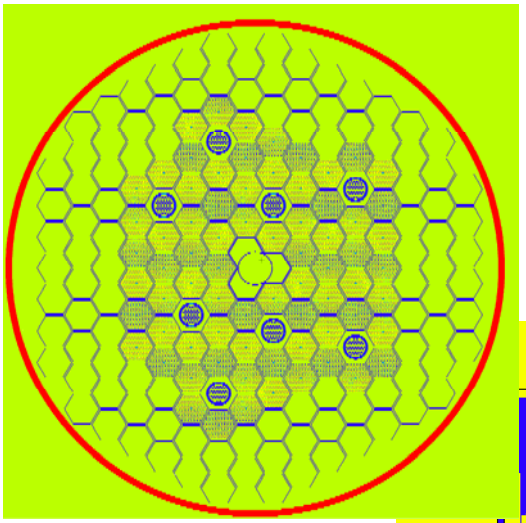
From C0 to P3

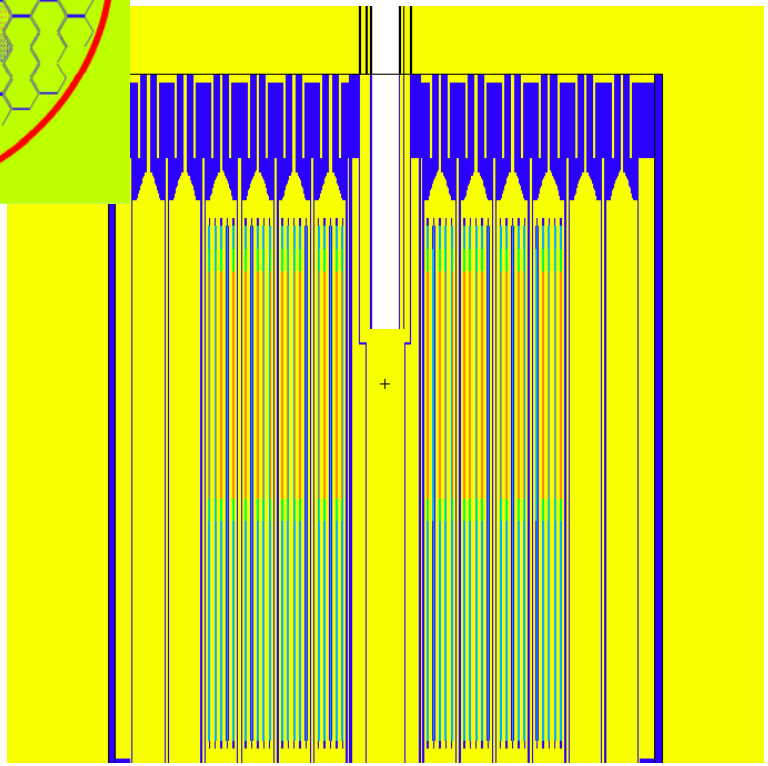






Core P3 case



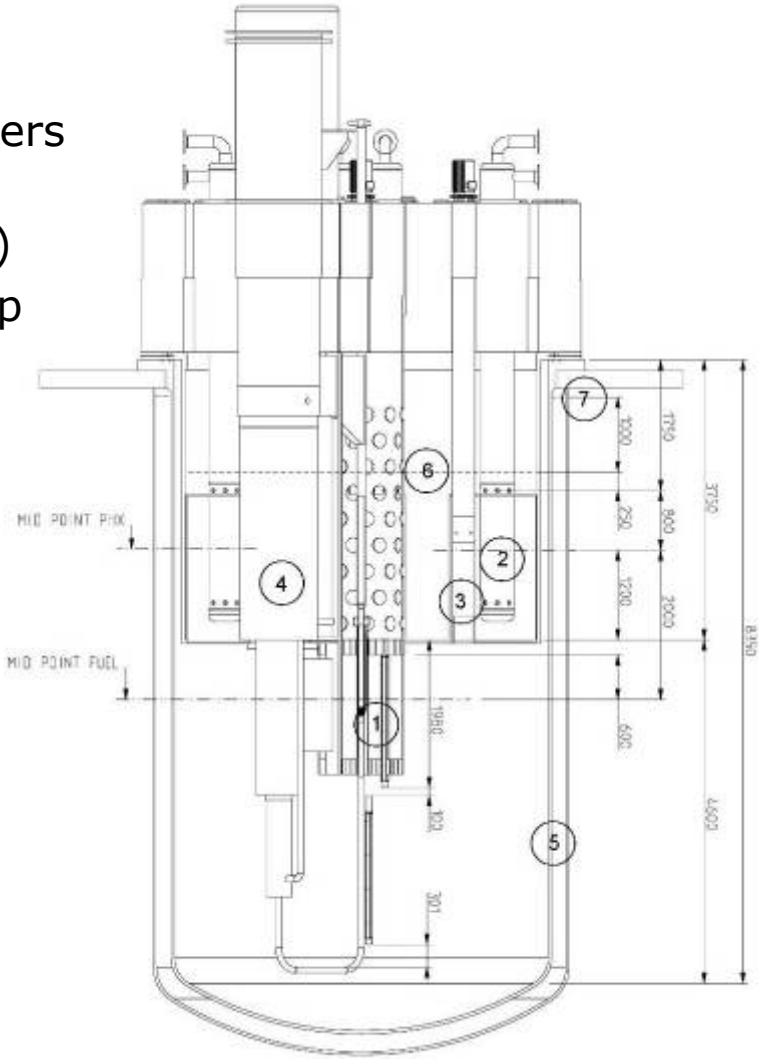


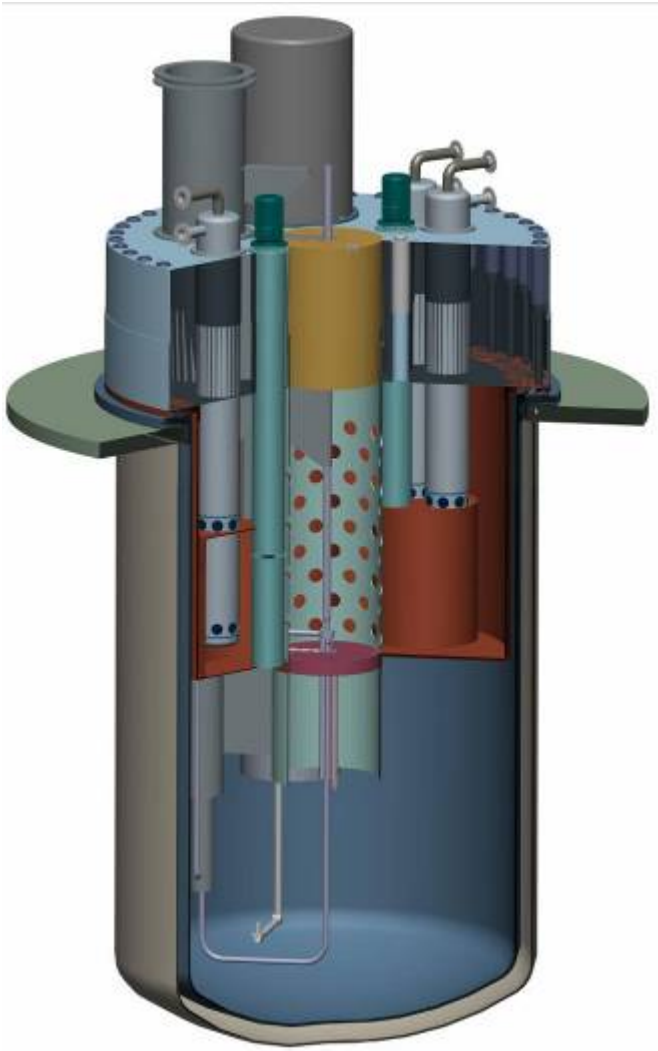
- Pu wt% = 33.80%
- k_{eff} = 0.95492
- K_s = 0.95936
- φ^*=1.11

- For I = 2.15 mA,
  P_{th} = 57 MW

MYRRHA overall configuration

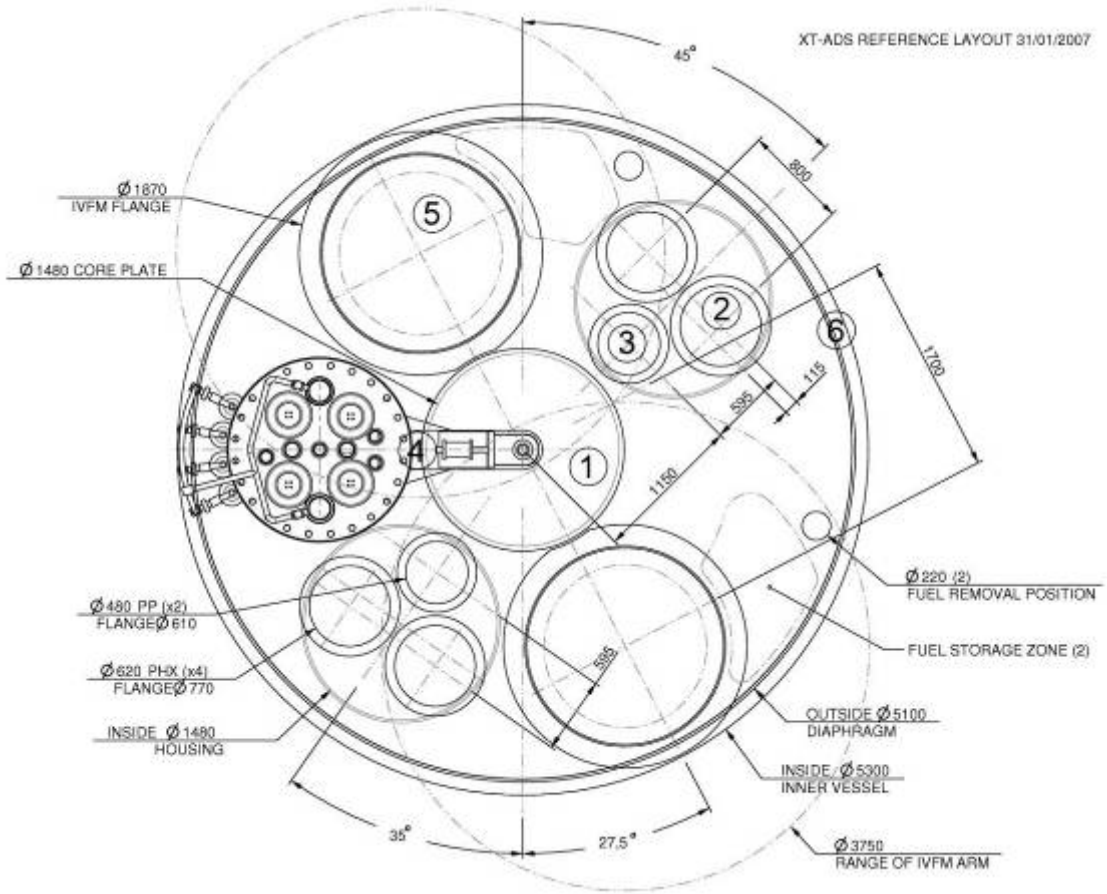
1. Core
2. Heat exchangers (2 x 2)
3. Pumps (2 x 1)
4. Spallation loop
5. Vessels
6. LBE hot level
7. LBE cold level





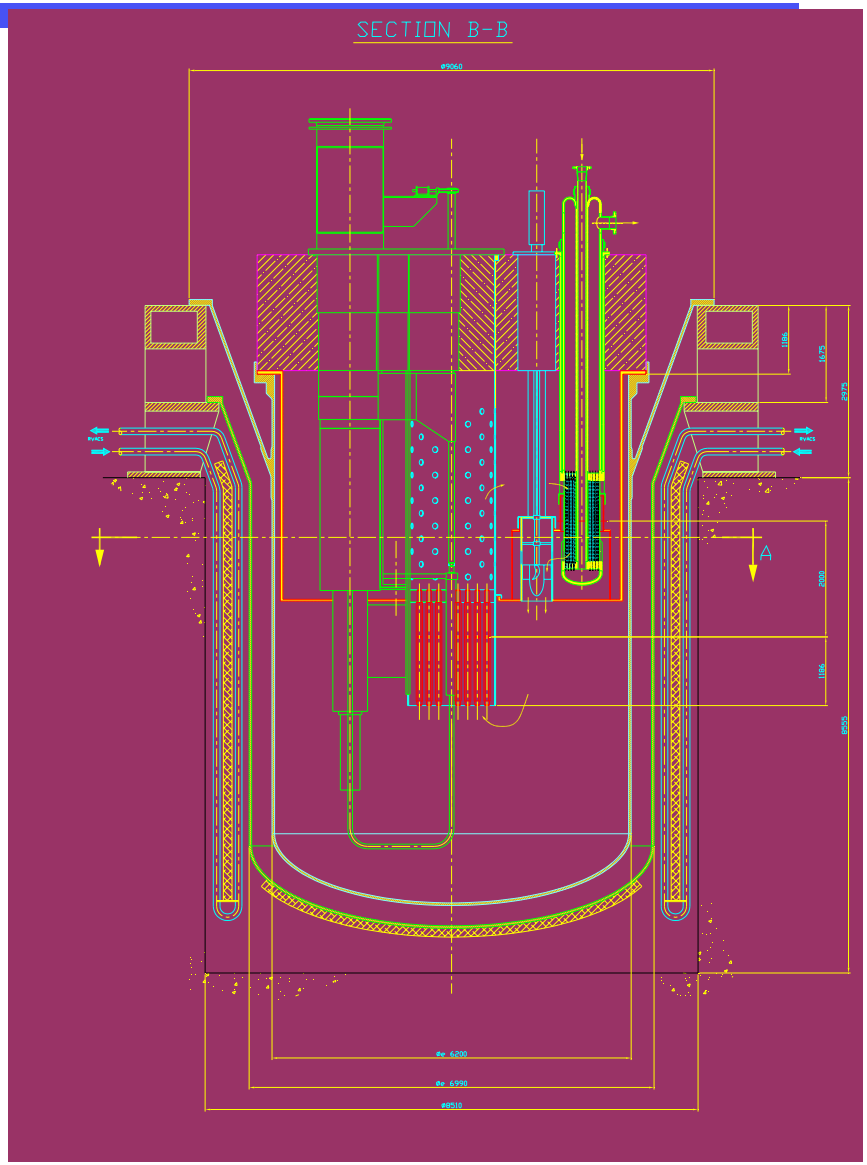
MYRRHA overall configuration

1. Core
2. Heat exchangers (2 x 2)
3. Pumps (2 x 1)
4. Spallation loop
5. Fuel manipulators (2 units)
6. Vessel



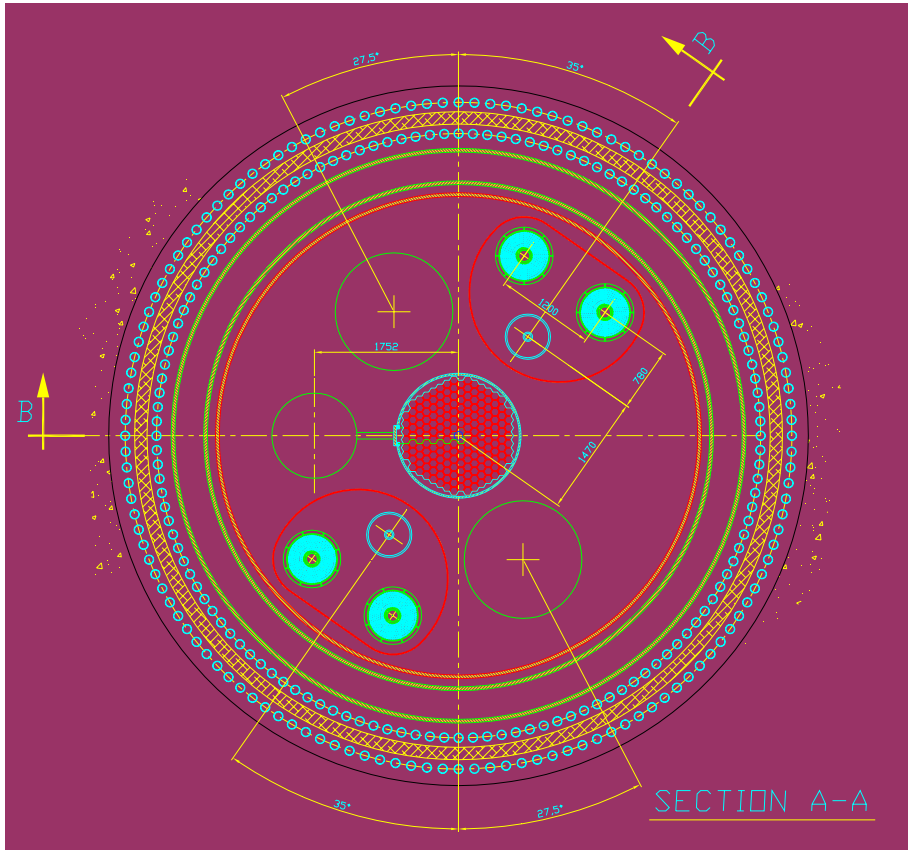
Last design proposed by ANSALDO (03.2008)

MYRRHA/XT-ADS
vertical section

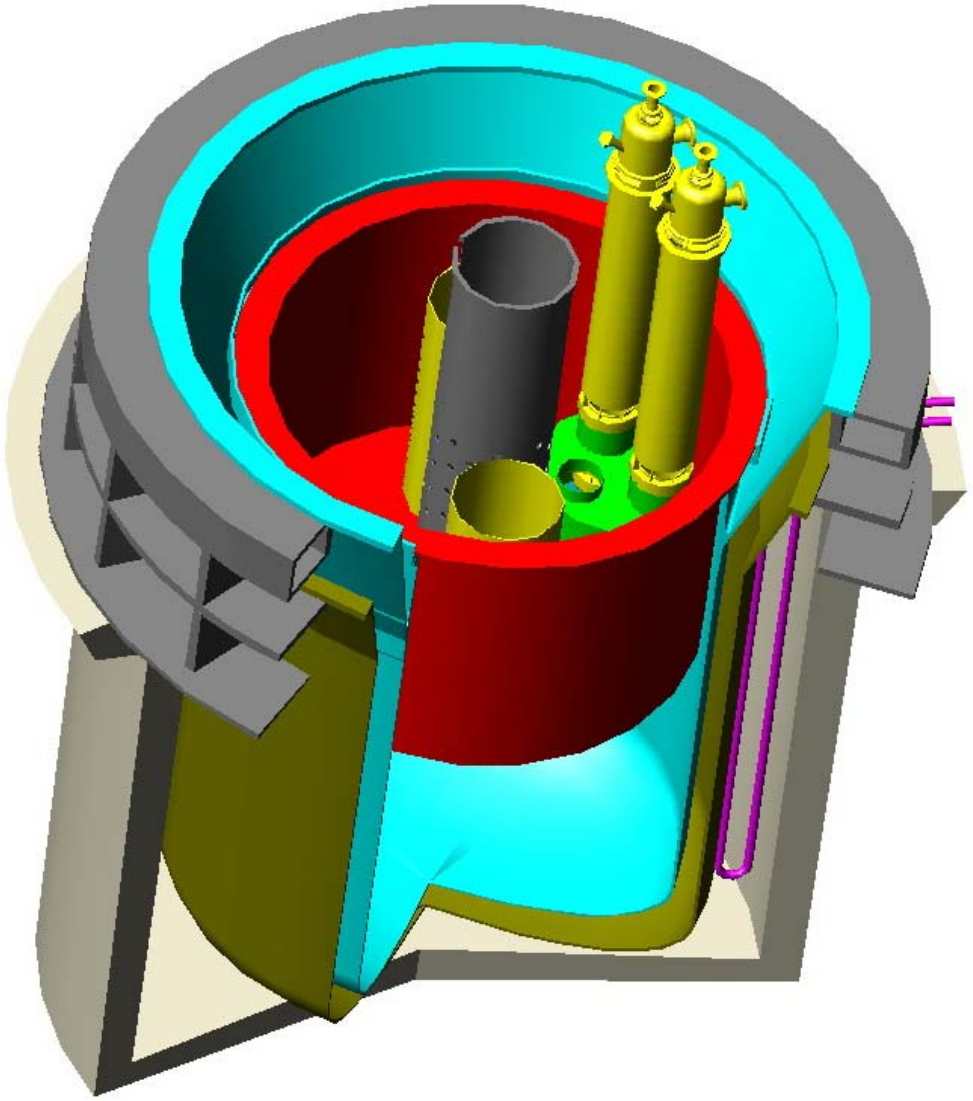


Last design proposed by ANSALDO (03.2008)

MYRRHA/XT-ADS
Transversal section



Last design proposed by ANSALDO (03.2008)



Roadmap towards realisation

- Technical challenges
- Project roadmap
- Project organisation
- Summary of costs
- Partnership building & involvement

Technical Challenges

- The project is supported by a comprehensive support R&D programme addressing the following technical challenges:
  - Accelerator reliability improvement
  - Windowless spallation target design, including vacuum interface compatibility
  - Pb-Bi technology: impurities filtering, Po migration
  - Material corrosion & erosion
  - Material embrittlement due to irradiation and LME
  - MOX fuel qualification under LBE and irradiation
  - Instrumentation development:
    - O_2-meters
    - HLM free surface monitoring
    - sub-criticality monitoring
    - ultrasonic visualisation
  - Robotics development for operation under Pb-Bi.

Some key dates (1/3)

- **MYRRHA**
  - **started as a collaboration** project between **SCK•CEN (B) and IBA (B) in 1998**
  - Since then **enlarged to other partners through bilateral collaboration agreements** (CEA, CNRS, ENEA, FZK, CIEMAT, JAEA, ISTC, OTL, IUS_KTU, IPUL, …)
  - **Since 03.2005** it serves as **basis of** the experimental ADS (**XT-ADS**) under development **within** the FP6 integrated project **EUROTRANS** within a consortium of 48 partners
  - EUROTRANS runs until **March 2009**

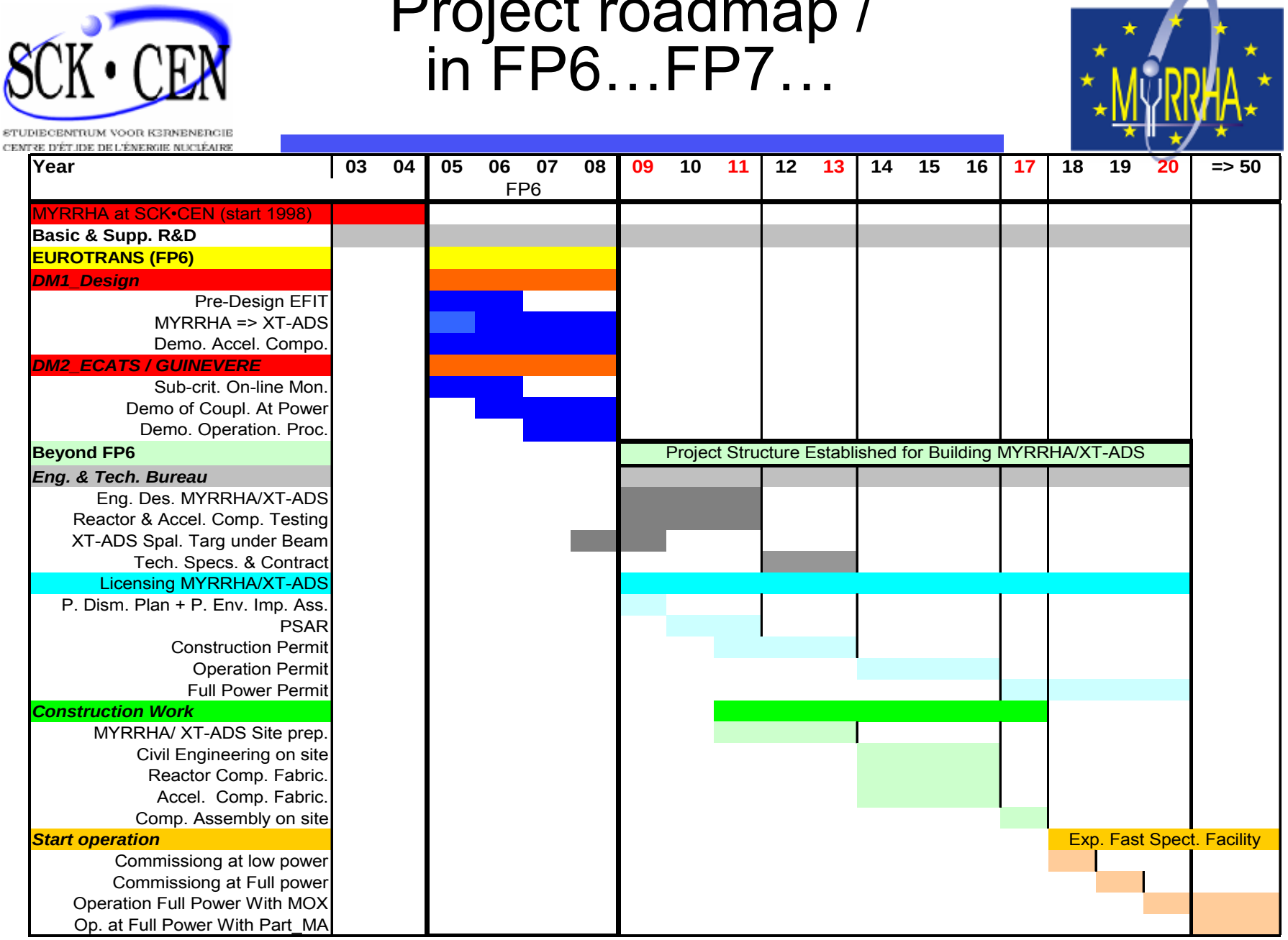
Some key dates (2/3)

- End 2008 ➔ submit Preliminary Decommissioning Plan to the waste management authorities – ONDRAF/NIRAS.
- 2009 – 2013 ➔ work in parallel on:
  - 2009 – 2011 : detailed engineering design (**FP7 CDT**)
  - 2012 – 2013 : drafting of technical specifications, publication of call for tenders, awarding of manufacturing contracts
  - 2009 – 2011 : testing of innovative components (for the accelerator and for the reactor);
  - 2009 – 2013 : licensing and permitting ➔ obtain the **authorization of construction at the end of 2013**

Some key dates (3/3)

- **2014 – 2016 : construction** of components & civil engineering works on the Mol site.
- **2017 : assembling** together the different components
- **2018 – 2019 : commissioning** (at progressive levels of power).
- **2020 : MYRRHA full Power operation**

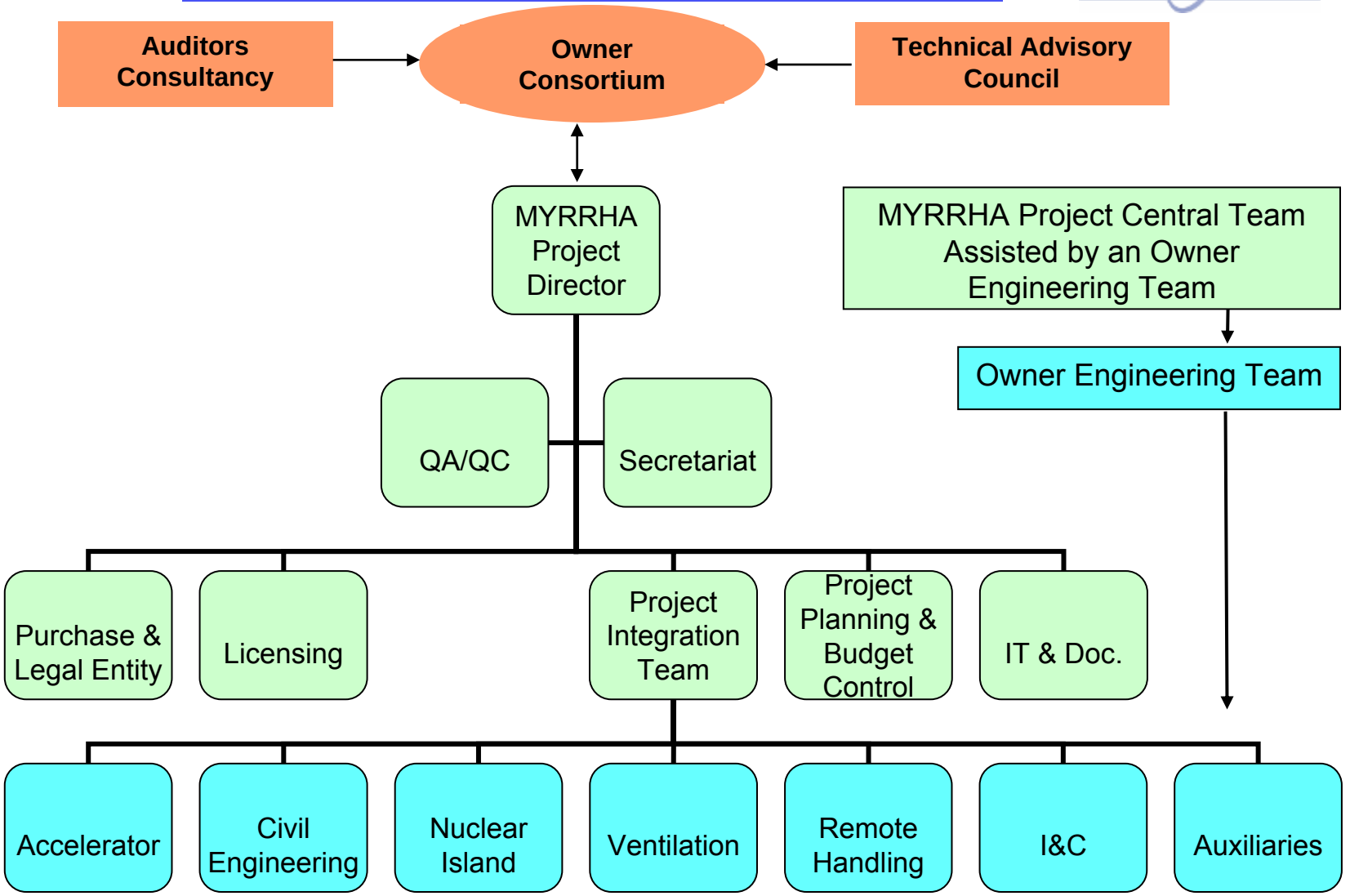
Project roadmap / in FP6…FP7…



MYRRHA project future organisation

- **From 2009 on MYRRHA will be organised as an International Entity** with:
  - An International Advisory Council
  - An Owner Consortium
  - A Project Central Management Team
  - A Users/Customers Group

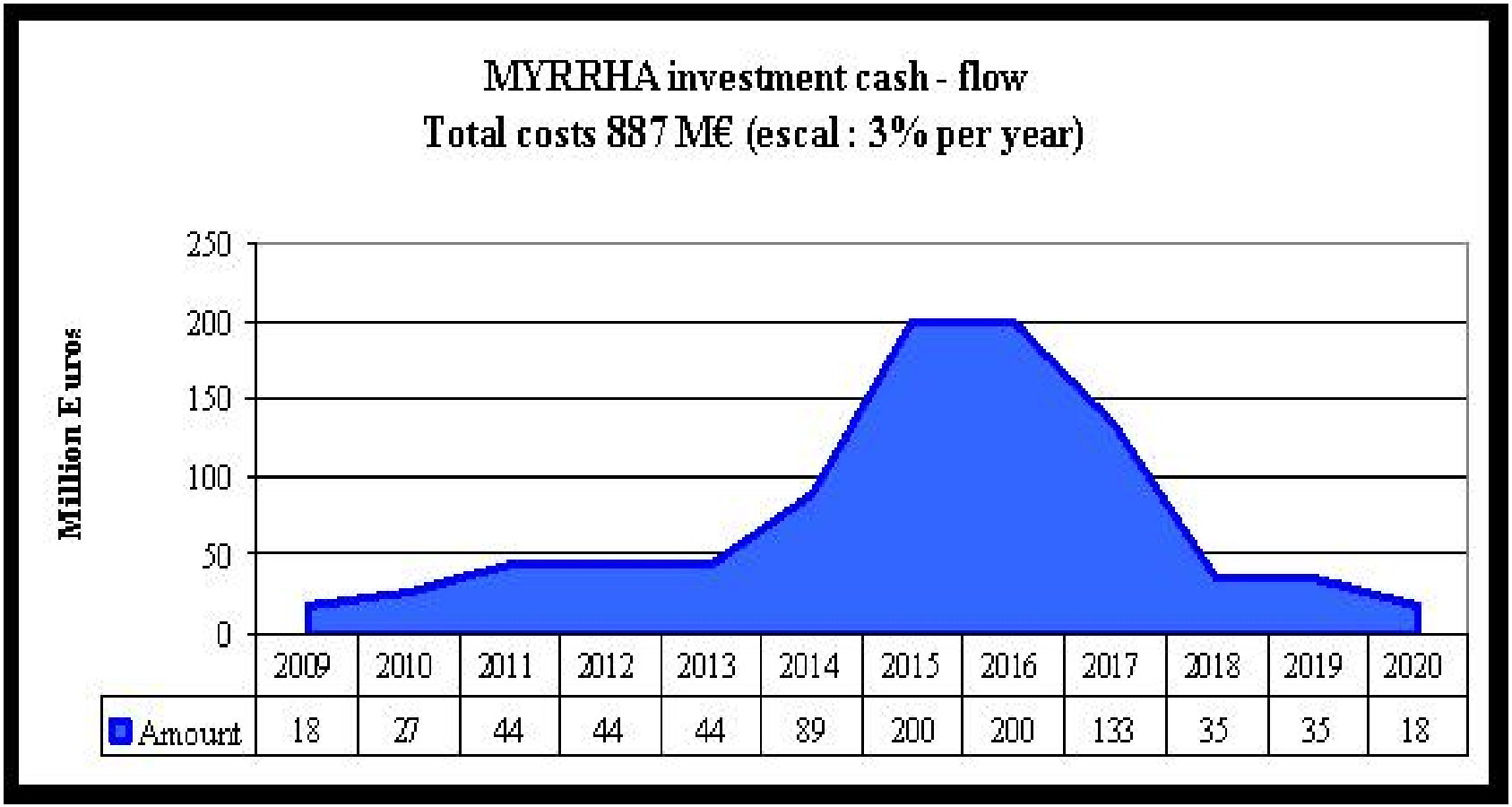
MYRRHA Project organisation



Summary of costs

- A Business Plan has been issued in **April 2007**
- The **total investment** costs expressed in current value (2007), spread over 12 years, amounts to: **~700 M€** including contingencies (**under revision**)
- This includes:
  - Total investment
  - Project management costs
  - Licensing costs
- **MYRRHA project is up for funding for 1/3 by Belgium and 2/3 by international partners**

Project financial life cycle



Partnership building & involvement

- MYRRHA/XT-ADS is proposed as an open user facility
- We are looking forward for establishing in 2008 an International Advisory Council to guide:
  - The further development of the facility
  - The creation of the Owner Consortium Group
  - The establishment of a Users/Customers Group of the facility
- **Today we are addressing one of the potential users community of the MYRRHA facility to be sure to meet your requests**

One picture is better than a thousand words, we are in 2017~2020